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Lisso et al.

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(54) **AIR PRESSURE ASSISTED CONVEYANCE SYSTEM**

(71) Applicant: **Amazon Technologies, Inc.**, Seattle, WA (US)

(72) Inventors: **Gregory Karl Lisso**, Bellevue, WA (US); **Steven Klehr**, Maple Valley, WA (US); **Sean Maylone**, Seattle, WA (US); **Laura Rubin**, Seattle, WA (US); **Vignesh Kumar Sivasamy**, Bellevue, WA (US); **Samuel Christopher Uhlman**, Kirkland, WA (US); **Scott Douglas King**, Seattle, WA (US)

(73) Assignee: **Amazon Technologies, Inc.**, Seattle, WA (US)

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(22) Filed: **Dec. 13, 2016**

(51) **Int. Cl.**

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B65G 43/08	(2006.01)
B65G 47/96	(2006.01)
B65G 17/34	(2006.01)
B65G 13/02	(2006.01)
B65G 51/03	(2006.01)

(52) **U.S. Cl.**
CPC ***B65G 43/08*** (2013.01); ***B65G 13/02*** (2013.01); ***B65G 17/345*** (2013.01); ***B65G 47/965*** (2013.01); ***B65G 51/03*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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2009/0129911	A1 *	5/2009	Jansen	B65G 21/2036 414/754
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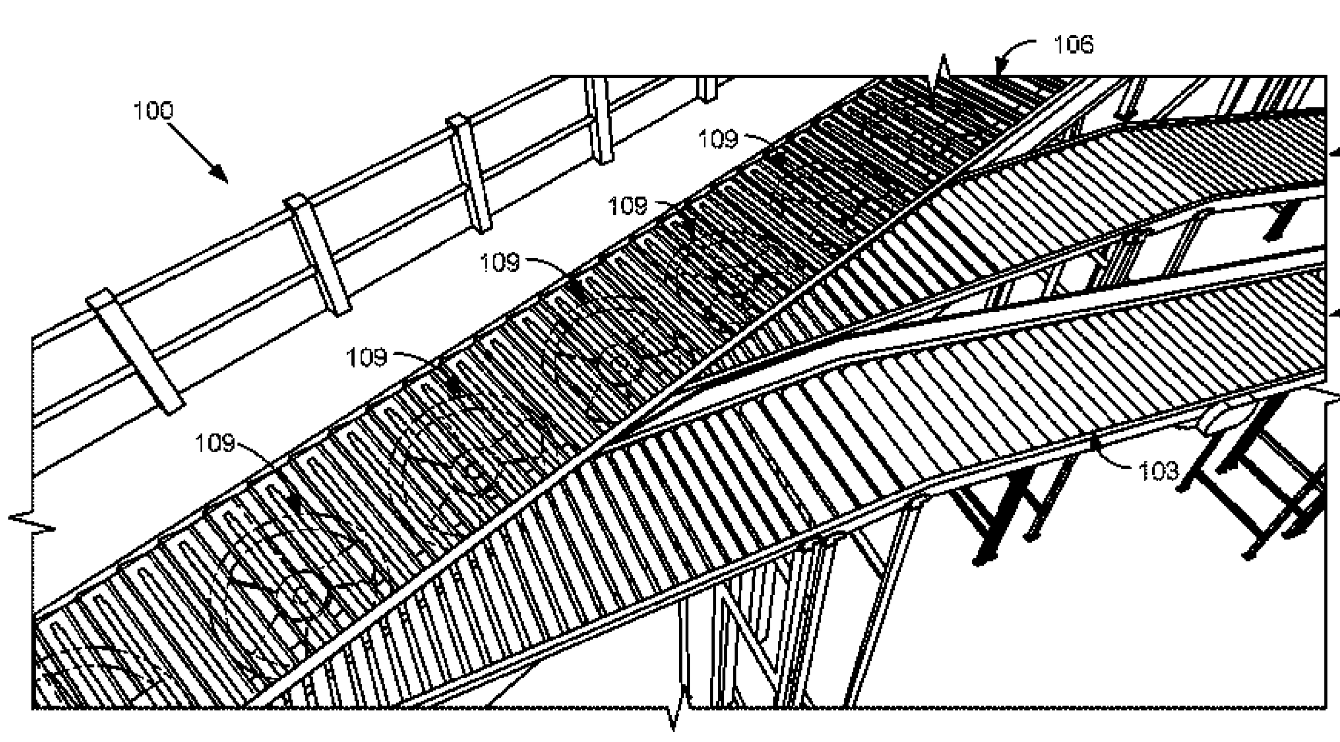
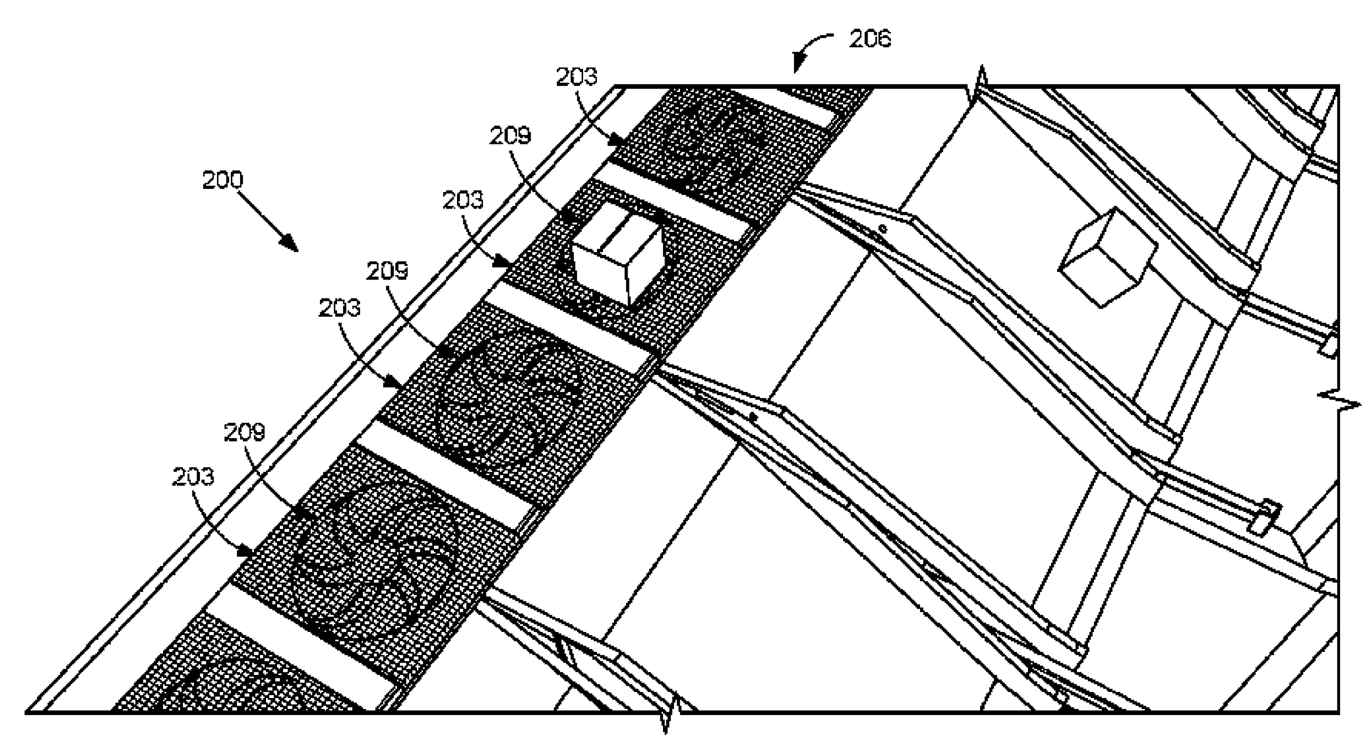
Primary Examiner — Yolanda R Cumbess
(74) *Attorney, Agent, or Firm* — Thomas Horstemeyer, LLP

(57) **ABSTRACT**

Disclosed are various embodiments for using air pressure to increase or decrease the force of static friction between an item and the surface of a conveyance system. The conveyance system can include a track and a conveyor segment affixed to the track. The conveyor segment can include an air permeable surface on which an item can be placed. Mounted underneath the air permeable surface is an air displacement device.

20 Claims, 11 Drawing Sheets





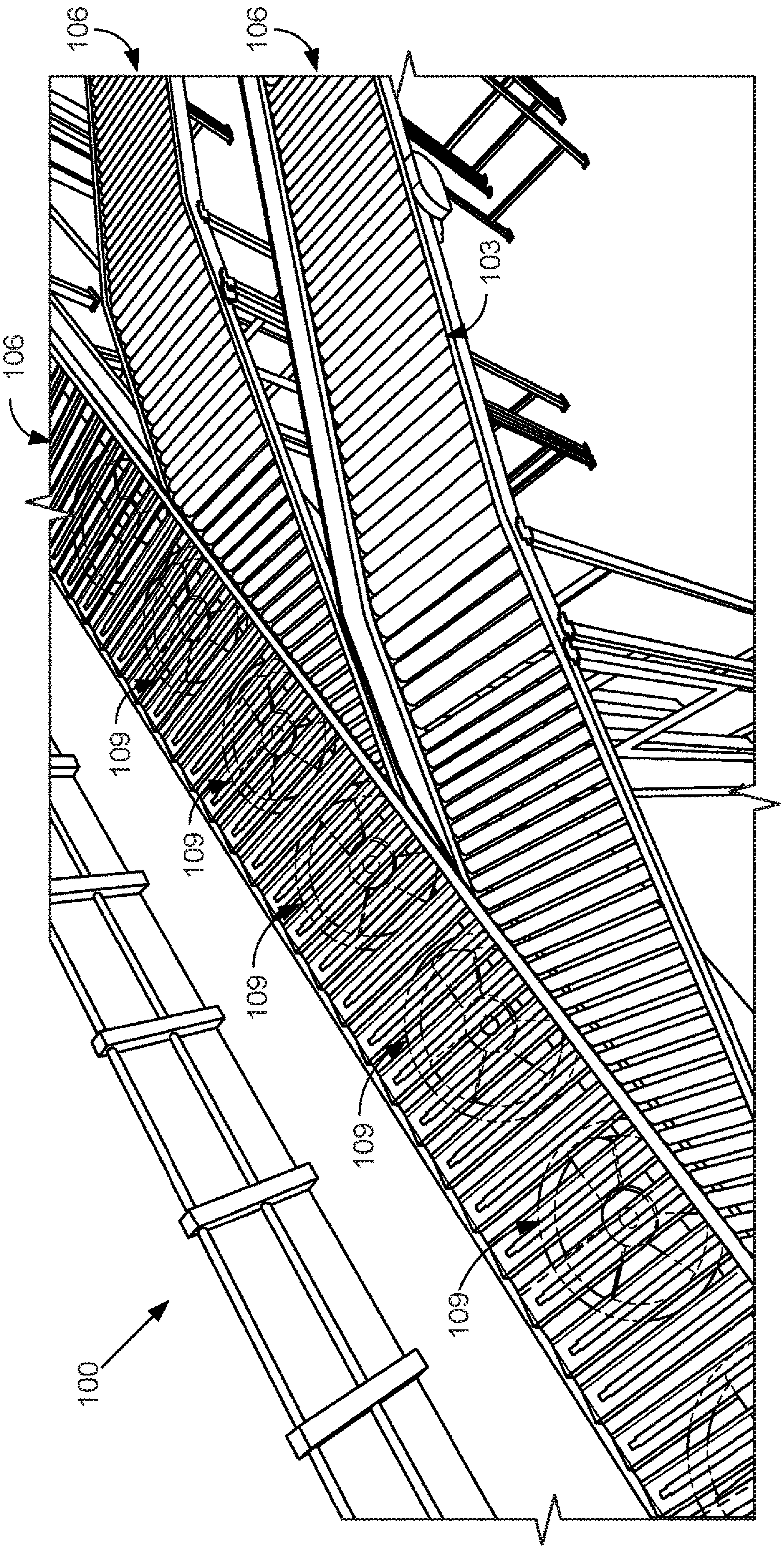


FIG. 1

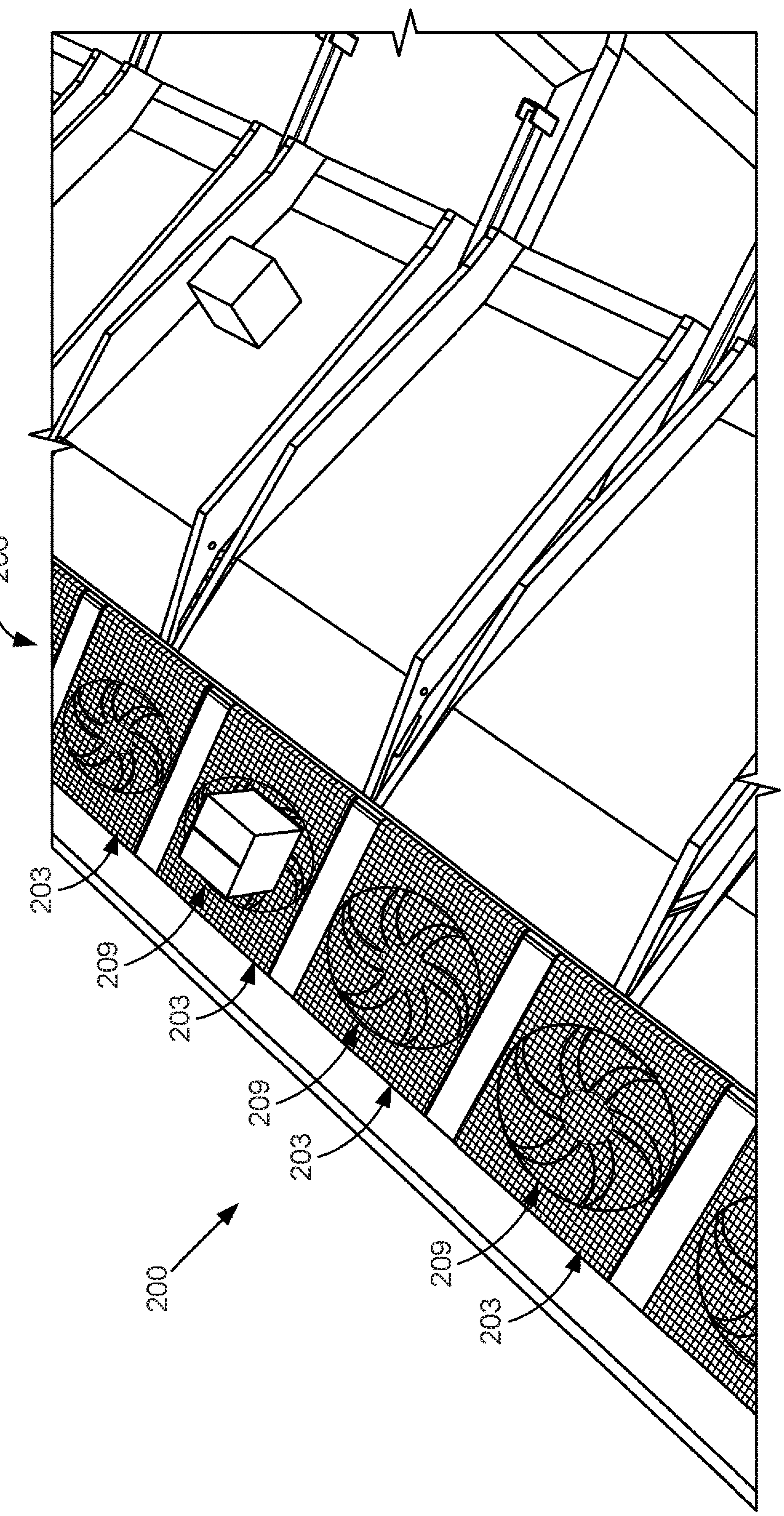


FIG. 2

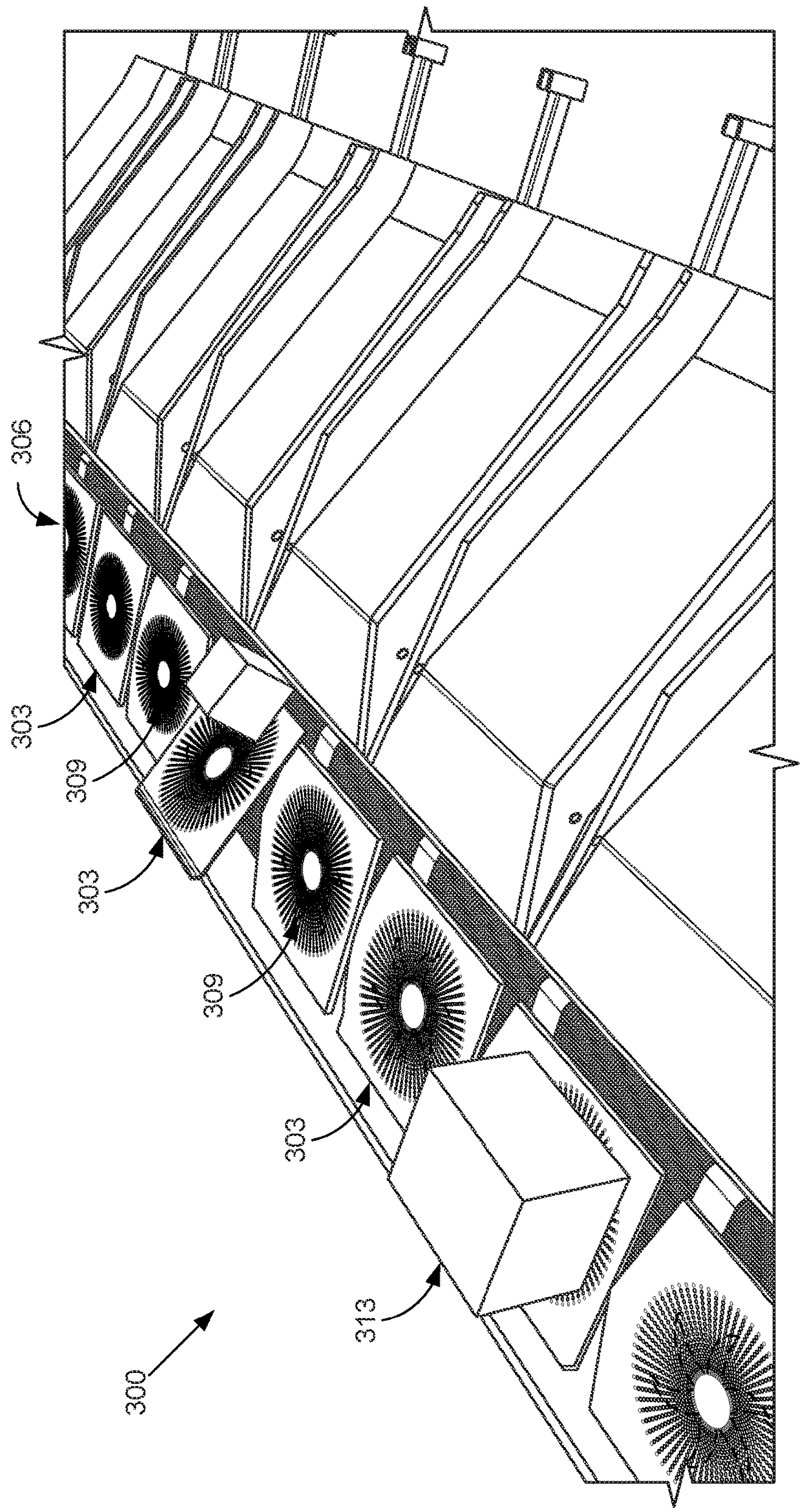


FIG. 3

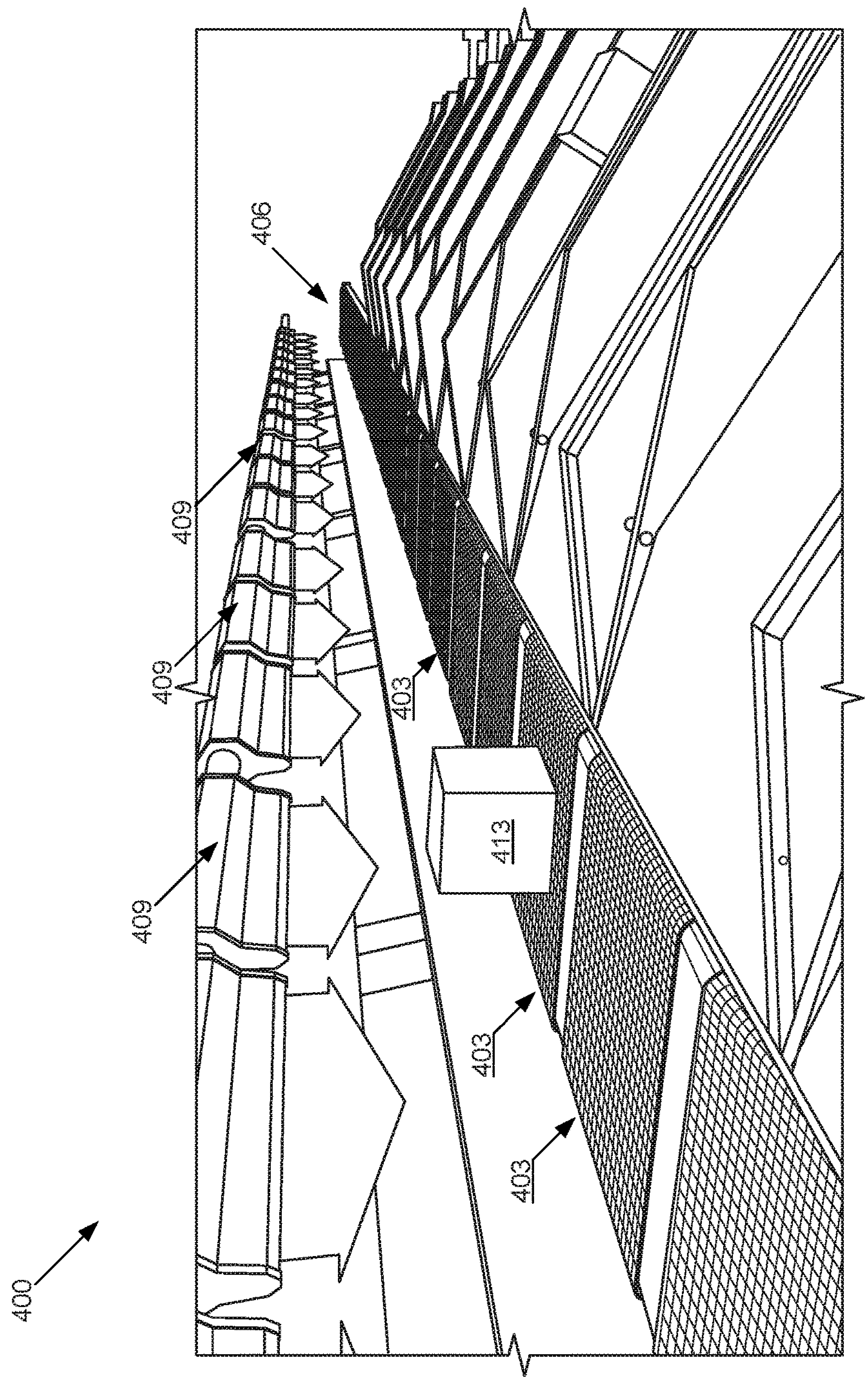


FIG. 4

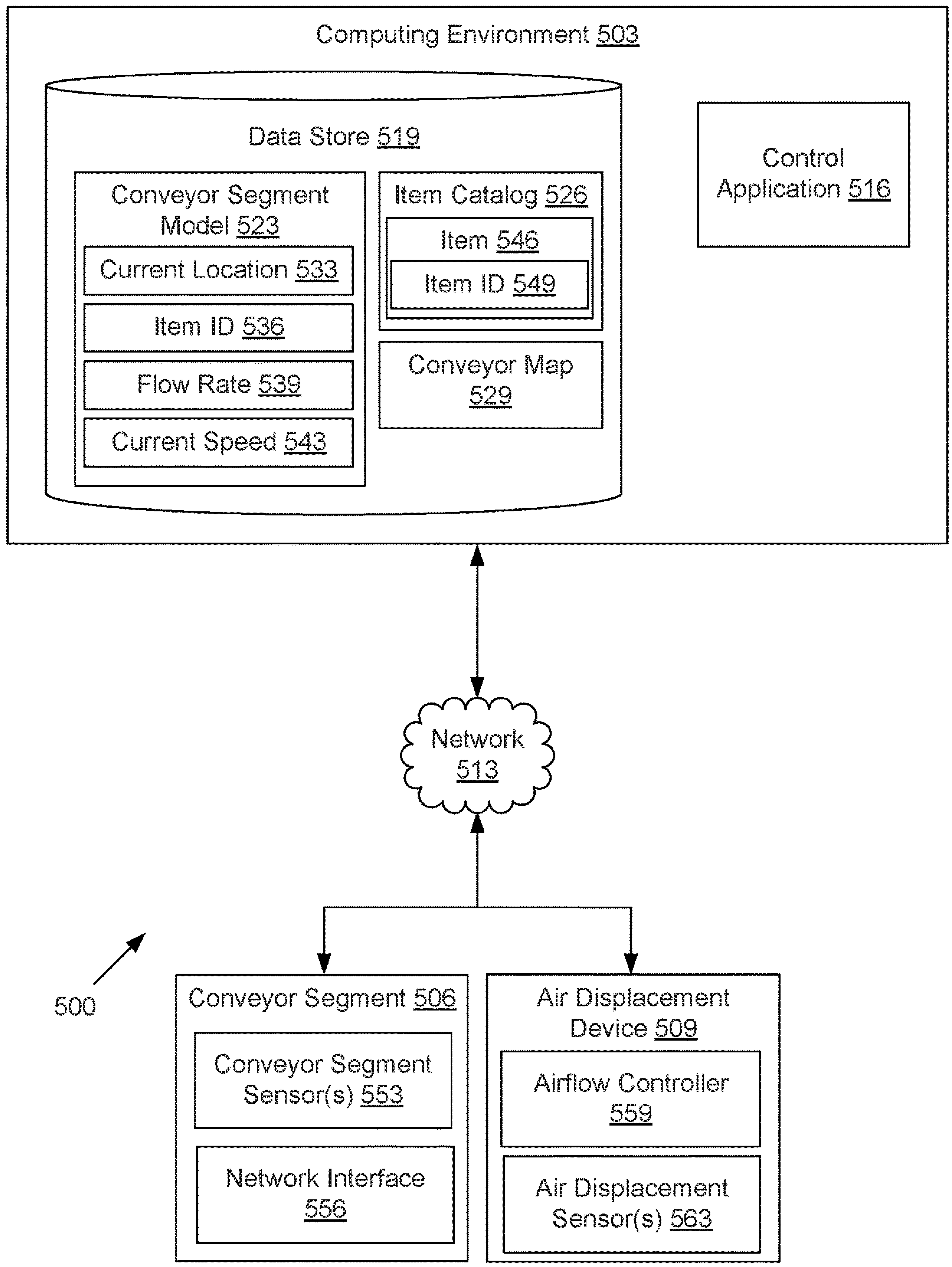

Computing Environment 503
Data Store 519
Conveyor Segment Model 523
Current Location 533
Item ID 536
Flow Rate 539
Current Speed 543
Item Catalog 526
Item 546
Item ID 549
Conveyor Map 529
Control Application 516
Network 513
500
Conveyor Segment 506
Conveyor Segment Sensor(s) 553
Network Interface 556
Air Displacement Device 509
Airflow Controller 559
Air Displacement Sensor(s) 563

FIG. 5

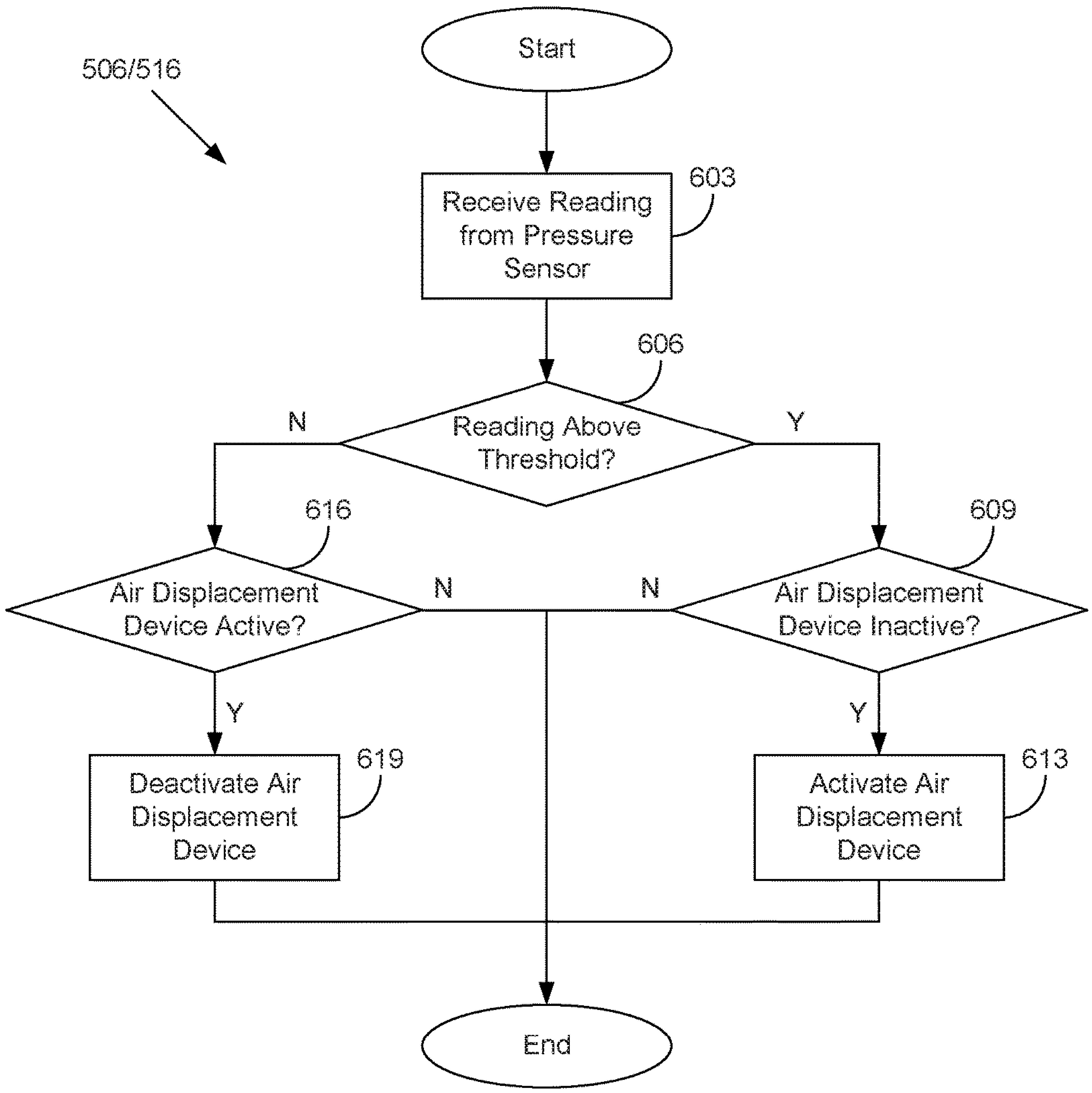

506/516
Start
Receive Reading from Pressure Sensor
603
606
Reading Above Threshold?
N
Y
616
609
Air Displacement Device Active?
N
N
Air Displacement Device Inactive?
Y
Y
Deactivate Air Displacement Device
619
Activate Air Displacement Device
613
End

FIG. 6

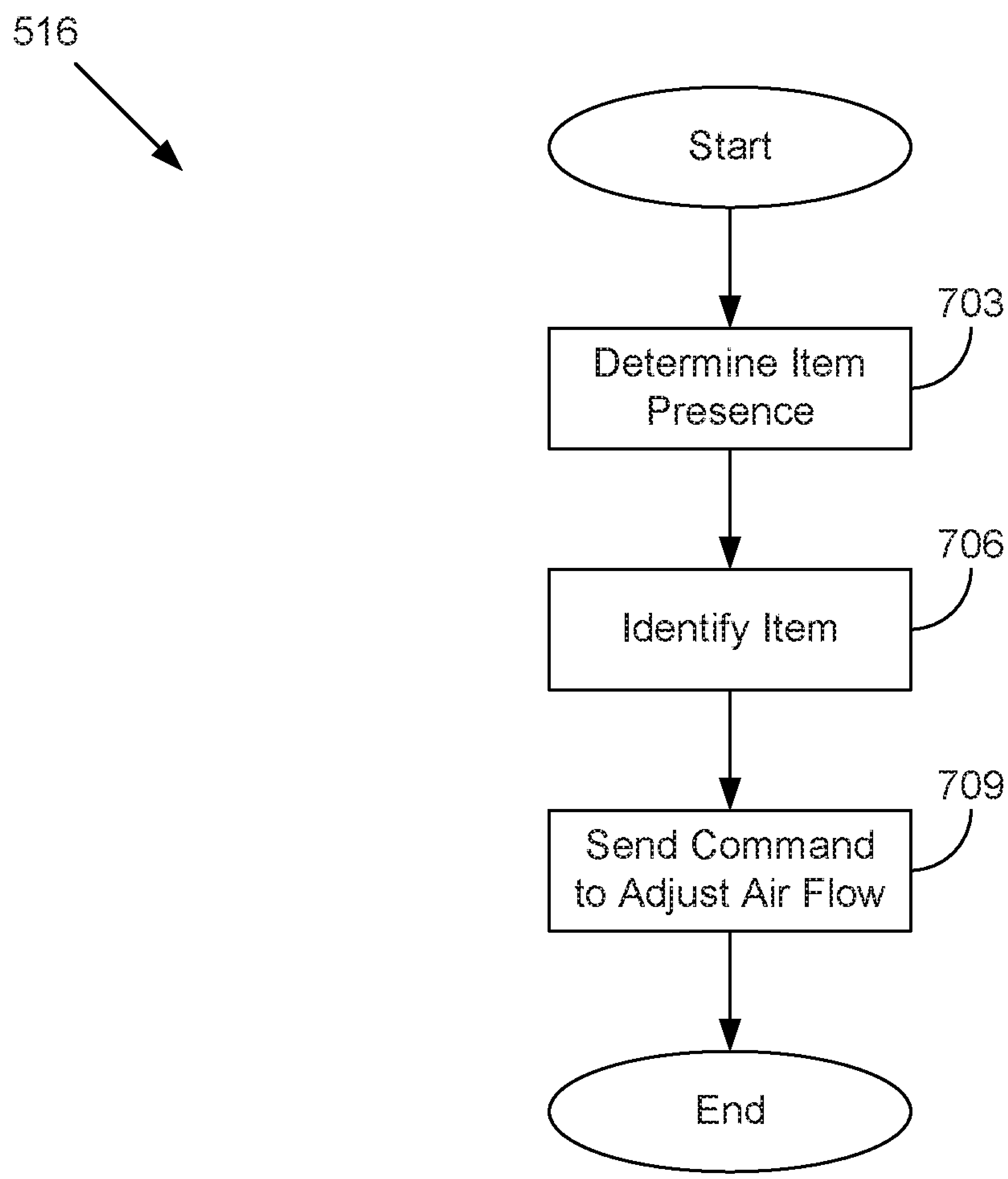

516
Start
703
Determine Item Presence
706
Identify Item
709
Send Command to Adjust Air Flow
End

FIG. 7

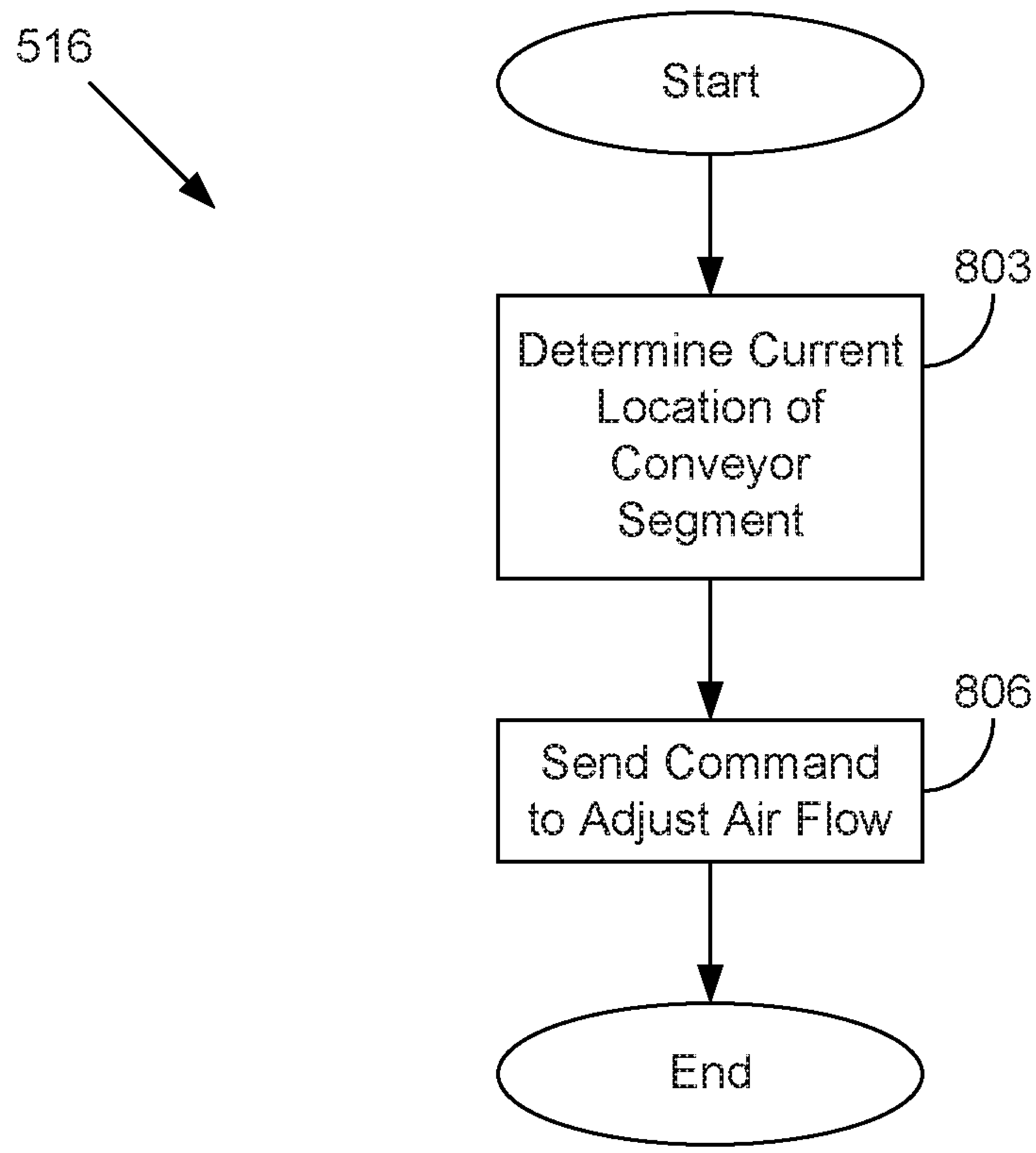

516
Start
803
Determine Current Location of Conveyor Segment
806
Send Command to Adjust Air Flow
End

FIG. 8

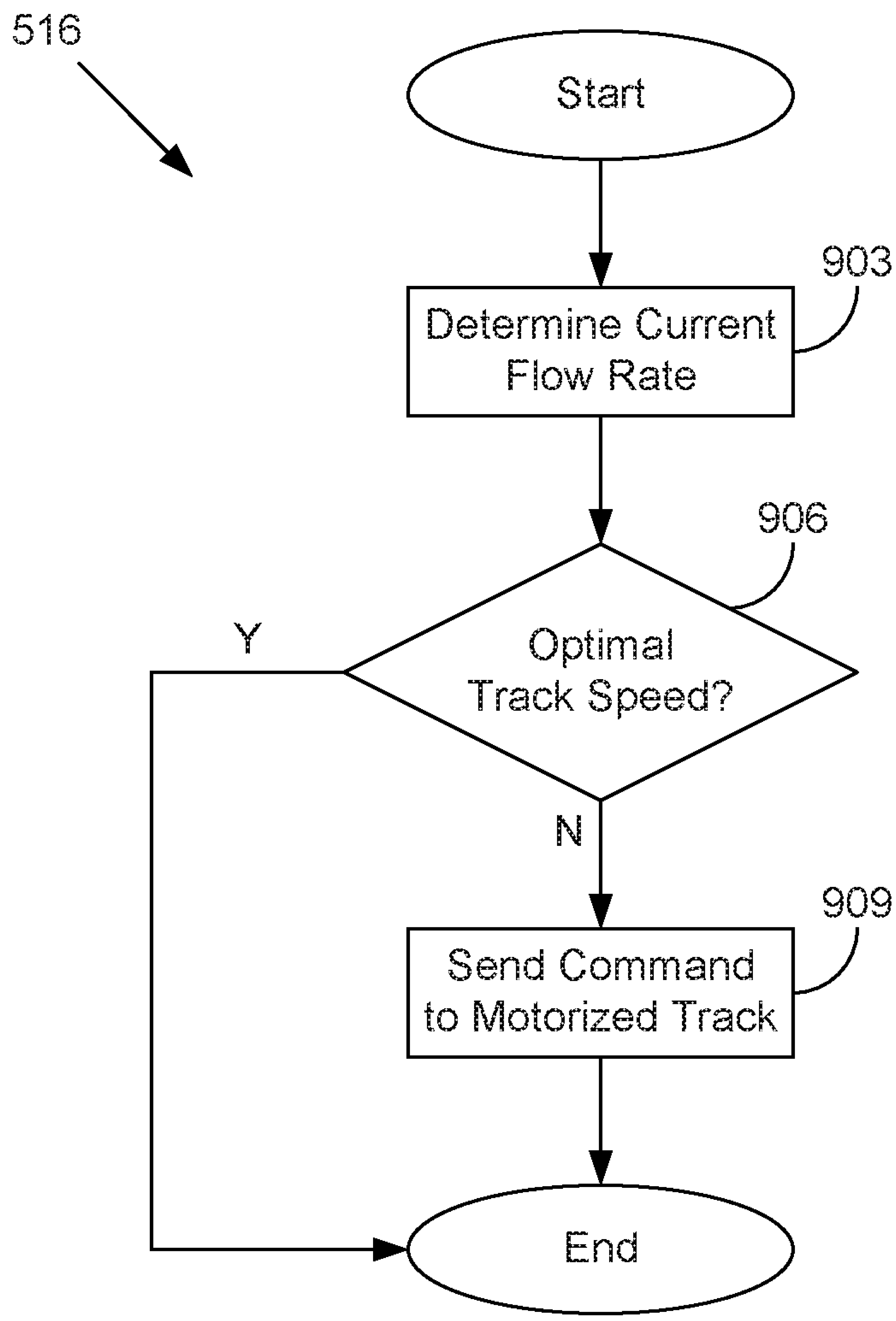

516
Start
903
Determine Current Flow Rate
906
Optimal Track Speed?
Y
N
909
Send Command to Motorized Track
End

FIG. 9

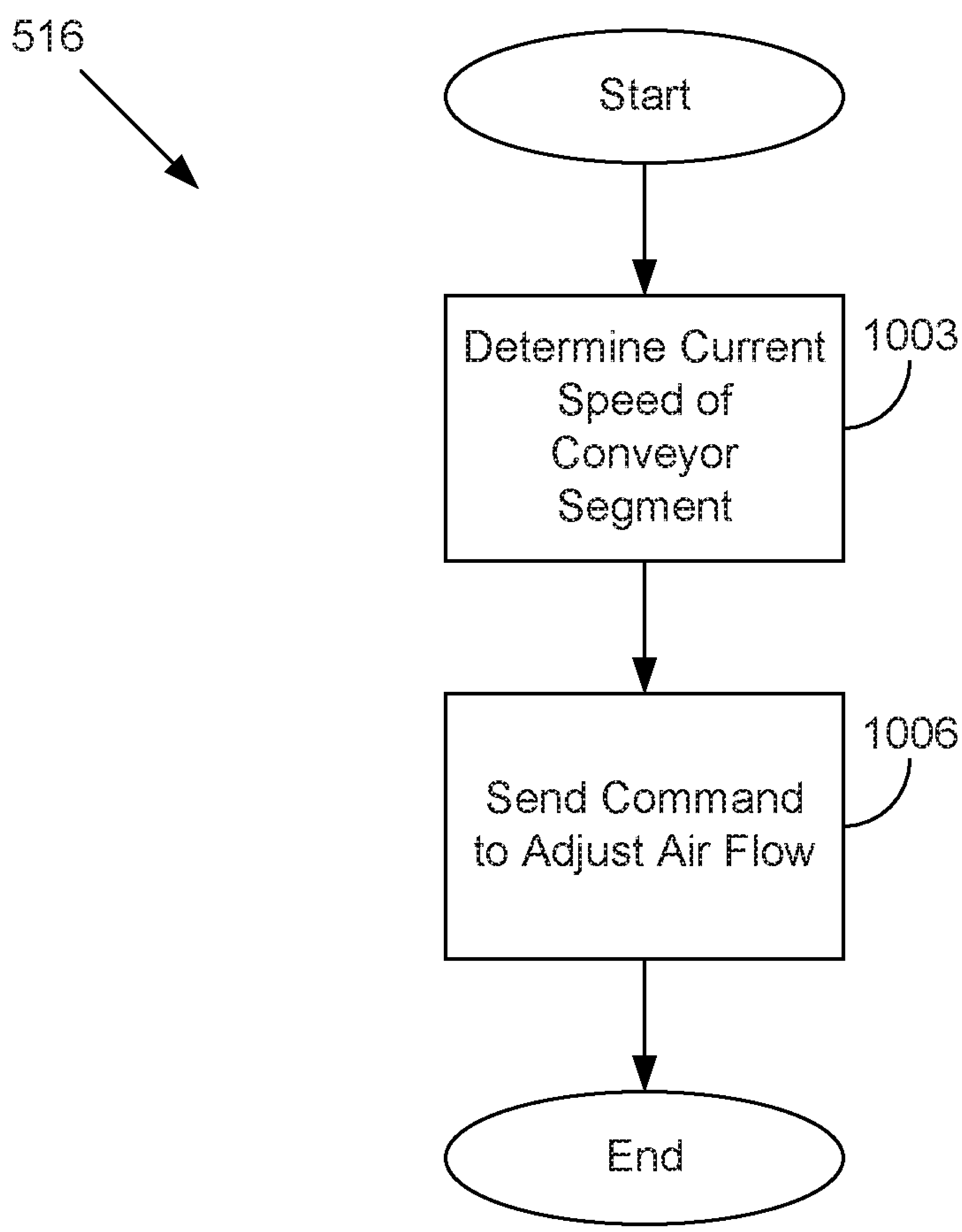

516
Start
Determine Current Speed of Conveyor Segment
1003
Send Command to Adjust Air Flow
1006
End

FIG. 10

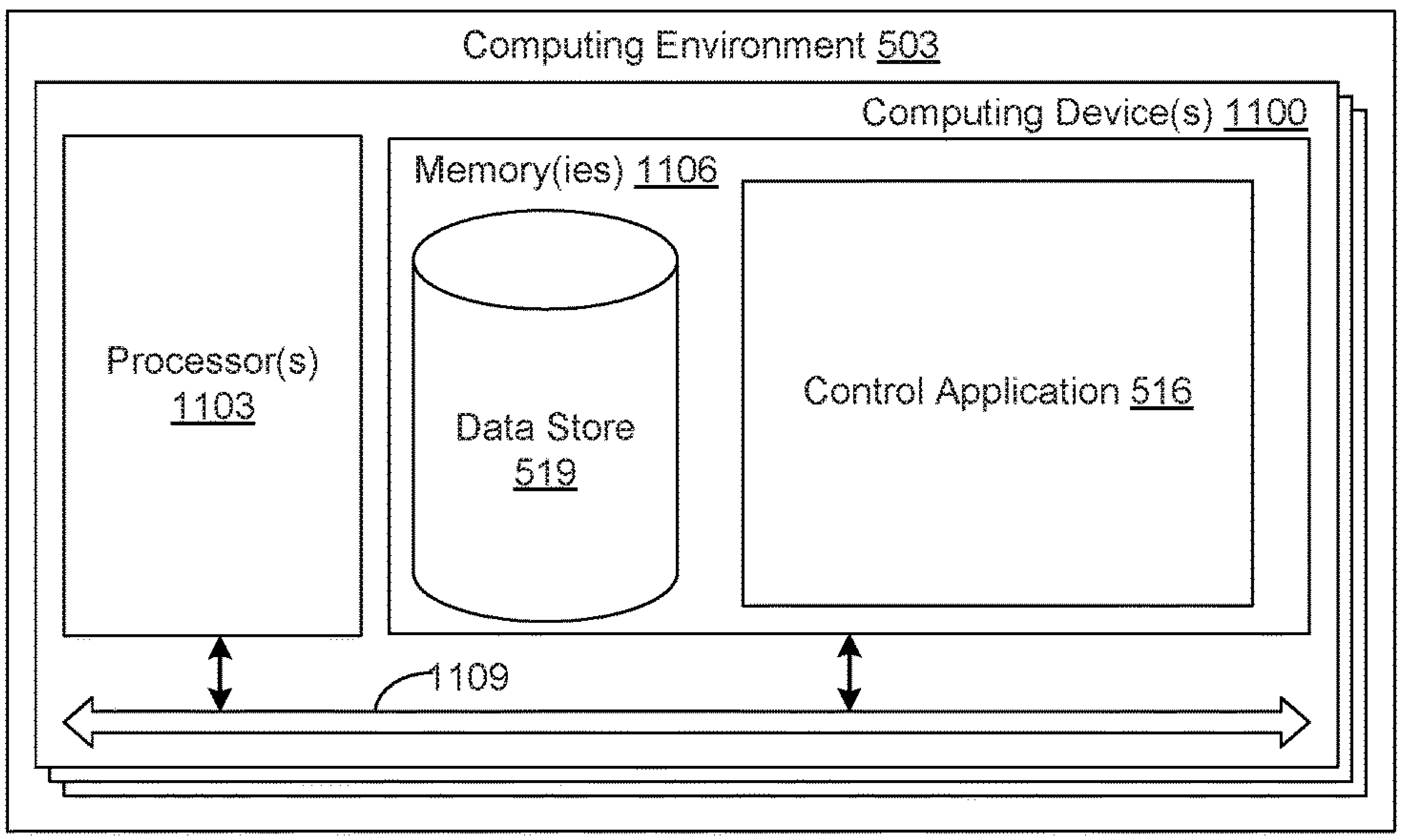

Computing Environment 503
Computing Device(s) 1100
Memory(ies) 1106
Processor(s) 1103
Data Store 519
Control Application 516
1109

FIG. 11

AIR PRESSURE ASSISTED CONVEYANCE SYSTEM

BACKGROUND

Logistics facilities (e.g., warehouses, shipping centers, etc.) often use materials handling systems to move items from one point to another or to sort items. Materials handling systems can include conveyor belts, beds, trays or similar devices. These materials handling systems often rely on gravity to anchor items to the materials handling systems as the items are moved.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a drawing depicting one of several embodiments of the present disclosure.

FIG. **2** is a drawing depicting one of several embodiments of the present disclosure.

FIG. **3** is a drawing depicting one of several embodiments of the present disclosure.

FIG. **4** is a drawing depicting one of several embodiments of the present disclosure.

FIG. **5** is a drawing of a networked environment according to various embodiments of the present disclosure.

FIG. **6** is a flowchart illustrating one example of functionality implemented as portions of an application executed in in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

FIG. **7** is a flowchart illustrating one example of functionality implemented as portions of an application executed in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

FIG. **8** is a flowchart illustrating one example of functionality implemented as portions of an application executed in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

FIG. **9** is a flowchart illustrating one example of functionality implemented as portions of an application executed in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

FIG. **10** is a flowchart illustrating one example of functionality implemented as portions of an application executed in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

FIG. **11** is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. **5** according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Disclosed are various embodiments of a conveyance system that uses air pressure to supplement the normal gravitational force of an item on a conveyance system by increasing the force of static friction between an item and the conveyance system at key points along a material handling path, e.g., during turns in a conveyance mechanism, or during sorting, when the item is acted on by forces that interrupt or alter the momentum of the item along the path.

By increasing the force of static friction between an item and the conveyance system, the conveyance system can be operated at higher speeds compared to conveyance systems that rely solely on gravity to hold an item in place using static friction. Due to the higher force of static friction, items are less likely to slip or lose contact with the conveyance system when operated at higher speeds. By increasing the force of static friction between the item and the conveyance system, the conveyance system can also be configured to make sharper turns, or traverse steeper inclines and declines compared to conveyance systems that rely solely on gravity to hold an item in place using static friction. Due to the higher force of static friction, items are less likely to slide off the conveyance system as a change in direction of travel (e.g., turning a corner) or a change in elevation (e.g., moving between levels or between stories in a building) occurs. In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same.

FIG. **1** depicts one of the various embodiments of the present disclosure. Here, a conveyance system **100** comprising a plurality of rollers **103** along several tracks **106** is depicted. One or more of the rollers **103** may be spun by one or more motors attached to a respective track **106**. As illustrated a number of fans **109** are mounted underneath the rollers **103** along one of the tracks **106**. The fans **109** can be spun to pull air down through the rollers **103**. This airflow applies additional downward force, in addition to gravity, thereby increasing the amount of fiction between the rollers **103** above the fans **109** and individual items. The gaps between the individual rollers **103** on the tracks **106** result in the track **106** acting as an air permeable surface through which the fans **109** can pull air.

FIG. **2** depicts an embodiment of a cross-belt sorter, according to various embodiments of the present disclosure. Here, a conveyance system **200**, such as a cross-belt sorter that includes a plurality of cross-belt segments **203** mounted to a track **206**, is depicted. Each cross belt segment **203** includes an air permeable conveyor belt that moves across the conveyor segment **203** at an angle relative to the track **206**. The air permeable conveyor belt can include a perforated belt, a chain-link belt, or other conveyor belt that allows air to pass through it. Here, the air permeable conveyor belts of the individual conveyor segments **203** that are depicted operate perpendicularly relative to the track **206** to move items into various slides.

Each cross-belt segment **203** can include an air displacement device **209**, such as a fan, suction pump, reverse Venturi valve, or similar device. In these instances, the air displacement device **209** is mounted to the cross-belt segment **203** beneath the air permeable conveyor belt. However, in other instances, the air displacement device **209** could be mounted to the track **206** in order to remain in a stationary position. In these instances, a cross-belt segment **203** would cross over an air displacement device **209** as the cross-belt segment moved along the track **206**. In either instance, as the air displacement device **209** draws air down through the air permeable conveyor belt, the resulting suction helps secure the item to the cross-belt segment **203**. Both the cross-belt segment **203** and the air displacement device **209** can be powered by an electric rail mounted to an interior surface of the track **206**.

FIG. **3** depicts an embodiment of a tilt-tray sorter, according to various embodiments of the present disclosure. Here, the conveyance system **300** includes a plurality of tilt-trays **303** mounted to a track **306**. Each tilt-tray **303** includes an air permeable surface on which an item can be placed. The air permeable surface can include, for example a perforated surface or other surface that allows air to pass through it.

Each tilt-tray **303** includes an air displacement device **309**, such as a fan, suction pump, reverse Venturi valve, or similar device. The air displacement device **309** is mounted beneath the air permeable surface of the tilt-tray **303**. As the air displacement device **309** draws air down through the air permeable surface, the resulting suction helps secure the item **313** to the tilt-tray **303**. Both the tilt-tray **303** and the air displacement device **309** can be powered by an electric rail mounted to an interior surface of the track **306**.

FIG. **4** depicts another one of the various embodiments of the present disclosure. Here, a conveyance system **400**, such as a cross-belt sorter that includes a plurality of cross-belt segments **403** mounted to a track **406**, is depicted. Each cross belt segment **403** includes an air permeable conveyor belt that moves across the conveyor segment **403** at an angle relative to the track **406**. The air permeable conveyor belt can include a perforated belt, a chain-link belt, or other conveyor belt that allows air to pass through it. Here, the air permeable conveyor belts depicted operate at a 90 degree angle relative to the track **406** to move items into various slides.

Above the track **406** is a series of air displacement devices **409**. An air displacement device **409** could include a fan, blower, or similar device. Each of the air displacement devices blows air down, as depicted by the arrow in FIG. **4**, onto the track **406**. The air flows through the air permeable conveyor belts of the individual cross-belt segments **403**, thereby applying positive air pressure to items **413** on their respective cross-belt segments **403**. In some embodiments, the air displacement devices **409** may be stationary. In other embodiments, the air displacement devices **409** can be mounted to their own track, allowing individual air displacement devices **409** to be moved synchronously with a corresponding cross-belt segment **403**.

FIG. **5** depicts a networked environment **200** according to various embodiments of the present disclosure. The networked environment **200** includes a computing environment **503**, a conveyor segment **506**, and an air displacement device **509**, which are in data communication with each other via a network **513**. The network **513** includes wide area networks (WANs) and local area networks (LANs). These networks can include wired or wireless components or a combination thereof. Wired networks can include Ethernet networks, cable networks, fiber optic networks, and telephone networks such as dial-up, digital subscriber line (DSL), and integrated services digital network (ISDN) networks. Wireless networks can include cellular networks, satellite networks, Institute of Electrical and Electronic Engineers (IEEE) 802.11 wireless networks (i.e., WI-FI®), BLUETOOTH® networks, microwave transmission networks, as well as other networks relying on radio broadcasts. The network **513** can also include a combination of two or more networks **513**. Examples of networks **513** can include the Internet, intranets, extranets, virtual private networks (VPNs), and similar networks.

The computing environment **503** may include, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment **503** may employ a plurality of computing devices that may be arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment **503** may include a plurality of computing devices that together may include a hosted computing resource, a grid computing resource or any other distributed computing arrangement. In some cases, the computing environment **503** may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

Various applications or other functionality may be executed in the computing environment **503** according to various embodiments. The components executed on the computing environment **503**, for example, include a control application **516** and other applications, services, processes, systems, engines, or functionality not discussed in detail herein.

The control application **516** is executed to control the operation of individual conveyor segments **506** and air displacement devices **509**. For example, the control application **516** can adjust the air flow generated by an air displacement device **509** to alter the amount of suction or lift generated by the air displacement device **509**. As another example, the control application **516** can increase or decrease the speed at which a track moves individual conveyor segments **506**.

Also, various data is stored in a data store **519** that is accessible to the computing environment **503**. The data store **519** may be representative of a plurality of data stores **519**, which can include relational databases, object-oriented databases, hierarchical databases, hash tables or similar key-value data stores, as well as other data storage applications or data structures. The data stored in the data store **519** is associated with the operation of the various applications or functional entities described below. This data can include conveyor segment models **523**, an item catalog **526**, a conveyor map **529**, and potentially other data.

The conveyor segment model **523** represents a data model of an individual conveyor segment **506**. Accordingly, the conveyor segment model **523** may include data such as the current location **533** of a conveyor segment **506**, an item identifier **536** of an item positioned on the conveyor segment **506**, a current air flow rate **539** representing the volume of air flowing over the modeled conveyor segment **506** or the air pressure applied to modeled conveyor segment **506**, and a current speed **543** of a conveyor segment **506**. The air flow rate **539** can represent the air flow or air pressure generated by the air displacement device **509**, as well as air flow or air pressure generated from other sources (e.g., ambient air pressure). The conveyor segment model **523** may also include additional state information about a corresponding conveyor segment **506**.

The item catalog **526** represents a list or catalog of items **546** that could be conveyed by a conveyor segment **506**. For individual items **546** stored in the item catalog **526**, information such as the weight and dimensions of the item **546** may be stored, as well as potentially other data (e.g., handling instructions). An individual item **546** may also be referenced by an item identifier **549**, allowing for an item **546** to be identified and information about the item **546** to be retrieved from the item catalog **526**.

The conveyor map **529** represents a map of the track that moves individual conveyor segments **506**. The conveyor map **529** stores information about the location of various sections of the track that moves the conveyor segments **506** in order for the control application **516** to determine the location of a conveyor segment **506** on the track. The information can include an identifier of the section (e.g. package ingress area, sorting area, package egress area, change in altitude or elevation, etc.).

The conveyor segment **506** represents a variety of potential conveyor segments **506** that could be used. A conveyor segment **506** could include a single conveyor belt extending the length of a track, a cross-belt segment used in a cross-belt sorter, a tilt-tray used in a tilt-tray sorter, or a similar segment used to transport an item with a materials handling and sorting system or apparatus. The conveyor segment **506** can include one or more conveyor segment sensors **553** and a network interface **556**.

A conveyor segment sensor **553** is sensor that measures a physical property of the conveyor segment **506** or detects an occurrence of an event. For example, a conveyor segment sensor **553** could include a speedometer that measures the speed at which the conveyor segment **506** is moving. As another example, a conveyor segment sensor **553** could include a radio frequency identification (RFID) reader to read an RFID tag affixed to an item **546** carried by the conveyor segment **506**. As a third example, a conveyor segment sensor **553** could include a pressure sensor or scale that detects the presence of an item **546** on the conveyor segment **506** and/or determines how heavy the item **546** is.

The network interface **556** represents a device connecting the conveyor segment **506** to the network **513**. Accordingly, the network interface **556** includes the circuitry necessary to communicate using the appropriate physical and/or data link layers of the network **513**. Examples of a network interface **556** include a wired Ethernet interface, a WI-FI interface, as well as various other interfaces.

The air displacement device **509** represents a device that can directionally displace air. Examples of an air displacement device **509** include a fan (e.g., an axial flow fan, a centrifugal fan, a cross-flow fan, etc.), an air pump (e.g., a suction pump, a Venturi valve or a reverse Venturi valve, etc.), an air blower, as well as similar devices. In some embodiments, the air displacement device **509** may be reversible (i.e., can blow air away from or suck air towards the air displacement device **509**). In some instances, the air displacement device **509** may be integrated into or mounted onto a conveyor segment **506**. In other instances, the air displacement device **509** may be physically separated from the conveyor segment **506**.

The air displacement device **509** can include an airflow controller **559** and one or more air displacement sensor(s) **563**, which may be in data communication with the control application **516**. The airflow controller **559** serves to control the rate at which air is displaced. For example, the airflow controller **559** could alter a fan motor speed or a pump motor speed to increase or decrease the rate at which air is displaced, or a flow control mechanism, e.g., one or more movable vanes, for varying the amount of air flowing into or out of the air displacement device. An air displacement sensor **563** measures the volume of air displaced and the rate at which it is displaced. The air displacement sensor **563** can accomplish this through several approaches. For example, the air displacement sensor **563** could measure the current speed (e.g., revolutions per minute) of the motor of the air displacement device **509** to calculate the air flow. As another example, the air displacement sensor **563** could correspond to an air vane that moves in proportion to airflow, allowing for airflow to be directly measured.

Next, a general description of the operation of the various components of the networked environment **500** is provided. To begin, one or more conveyor segments **506** located on a track are put into motion. As the conveyor segments **506** move along the track, items **546** are placed on individual ones of the conveyor segments **506**.

After an item **546** is placed on a conveyor segment, its presence may be reported to the control application **516** by the conveyor segment **506**. Some additional information about the item **546** (e.g., weight, size, identifier, etc.) may also be reported to the control application **516**. Information about the item **546** can be used by the control application **516** to determine an appropriate flow rate **539** or resulting air pressure for a respective air displacement device **509** to generate.

Additional information may also be provided to or determined by the control application **516**. This information can include the current location **533** of the conveyor segment **506** on a conveyor map **529**, the current speed **543** of the conveyor segment **506**, a flow rate **539** for air flow generated by a respective air displacement device **509**, and potentially other data. This additional information can also be used by the control application **516** to determine an appropriate flow rate **539** for a respective air displacement device **509** to generate

The control application **516** can then determine what an appropriate flow rate **539** would be for the air displacement device **509**. Different items **549** may require different flow rates **539** in order to achieve a target force of static friction between the item **549** and the surface of the conveyor segment **506**. Static friction is equal to the product of the normal force between an object and the surface on which it rests multiplied by the coefficient of static friction for that particular surface. Accordingly, heavier items **549** may require less air pressure to maintain a target force of static friction with the surface of the conveyor segment **506** than a lighter item **546** due to the magnitude of the normal force generated from the weight of heavier items **549**. Likewise, a higher flow rate **539** may be required to achieve a target force of static friction for lighter items **546** because the magnitude of the normal force for lighter items **549** is too small given the weight of the lighter items. In both cases, the normal force can be adjusted by applying a positive air pressure or negative air pressure to an item **549**, resulting in an increase or decrease of the force of static friction. As another example, higher target forces of static friction between an item **546** and the surface of the conveyor segment **506** may be required in order to move the conveyor segments **506** along a track at higher speeds. In other examples, changes in elevation of a conveyor segment, which can be determined based at least in part on the current location **533** of a conveyor segment **506**, may require higher target forces of static friction (and accordingly higher flow rates **539**) in order to prevent items **546** from either flying off of the conveyor segment when the conveyor angles downward, or tipping over when the conveyor inclines upward. Accordingly, the control application **516** could instruct an air displacement device **509** to adjust a flow rate **539** (e.g., increase the flow rate **539** or decrease the flow rate **539** as the situation warrants) for a conveyor segment **506** based at least in part on one or more of these factors.

Once the control application **516** determines a target flow rate **539** for a respective air displacement device **509**, the control application **516** determines whether the current flow rate **539** matches the target flow rate **539**. If the current flow rate **539** fails to match the target flow rate **539**, the control application **516** can send a command or instruction to the airflow controller **559** of the respective air displacement device **509** to increase or decrease the current flow rate **539** to match the target flow rate **539**.

In some instances, the conveyor segment **506** can be configured to communicate with the airflow controller **559** to modify the flow rate **539** without the intervention of the control application **516**. For example, the conveyor segment **506** can use one or more conveyor segment sensors **553** to determine whether an item **546** is present on the conveyor segment **506**. If an item **546** is determined to be present, control circuits in the conveyor segment **506** could automatically instruct the airflow controller **559** of a respective air displacement device **509** to activate the air displacement device **509**. Similarly, if conveyor segment sensors **553** determine that an item **546** has been removed, control circuits in the conveyor segment **506** could automatically instruct the airflow controller **559** to deactivate the air displacement device **509**. As an illustrative example, the conveyor segment **506** could include a pressure sensor that, when activated, causes the airflow controller **559** to activate the air displacement device **509**. Similarly, when the pressure sensor is deactivated, the airflow controller **559** would deactivate the air displacement device **509**. A weight scale could similarly be used, where zero weight causes the airflow controller **559** to deactivate the air displacement device **509**, a low weight causes the airflow controller **559** to run at reduced speed or airflow, and a large weight causes the airflow controller **559** to run at full speed or airflow.

Referring next to FIG. **6**, shown is a flowchart that provides one example of the operation of a portion of the conveyor segment **506** according to various embodiments. It is understood that the flowchart of FIG. **6** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the conveyor segment **506** as described herein. As an alternative, the flowchart of FIG. **6** may be viewed as depicting an example of elements of a method implemented in conveyor segment **506** according to one or more embodiments.

Beginning with box **603**, control circuitry on the conveyor segment **506** receives a reading from a conveyor segment sensor **553** (FIG. **5**), such as a pressure sensor. The reading can indicate that an item **546** (FIG. **5**) has been placed on the conveyor segment **506** or that an item has been removed from the conveyor segment **506**. For example, an increase in the measured weight or pressure could indicate that item **546** has been placed on the conveyor segment **506** while a decrease in the measured weight or pressure could indicate that the item **546** has been removed from the conveyor segment **506**.

Proceeding to box **606**, the control circuitry on the conveyor segment **506** determines whether the reading received from the conveyor segment sensor **553** is above or below a predefined threshold value in order to determine whether an item **546** has been placed on top of or removed from the conveyor segment **506**. For example, if the reading is above a threshold value (corresponding to the additional weight of an item **546** added to the conveyor segment **506**), then the process proceeds to box **609**. However, if the is below a threshold value (corresponding to the decrease in measured weight as a result of an item **546** being removed from the conveyor segment **506**), then the process proceeds instead to box **616**.

If process proceeds to box **609**, the control circuitry on the conveyor segment **506** checks the state of the air displacement device **509** (FIG. **5**) to see if it is currently inactive. For example, the control circuitry on the conveyor segment **506** may send a signal or a request to the airflow controller **559** (FIG. **5**) to determine if the air displacement device **509** is currently inactive (e.g., query to see if a fan motor is currently not running). If the air displacement device **509** is currently inactive, the process proceeds to box **613**. However, if the air displacement device **509** is active, then the process subsequently ends.

Moving to box **613**, the control circuitry on the conveyor segment **506** activates the air displacement device **509**. For example, the control circuitry could send a signal or message to the airflow controller **559** that instructs the airflow controller **559** to turn on the motor controlling the air displacement device **509** (e.g., a fan motor). As another example, the control circuitry could send a signal or message to the airflow controller **559** that instructs the airflow controller **559** to adjust or increase the amount of air being displaced by the air displacement device (e.g., increase speed of fan motor from a lower speed to a higher speed). Execution of the process then subsequently ends.

However, if the process instead proceeded from box **606** to box **616**, then the control circuitry on the conveyor segment **506** checks the state of the air displacement device **509** to see if it is currently active. For example, the control circuitry on the conveyor segment **506** may send a signal or a request to the airflow controller **559** to determine if the air displacement device **509** is currently active (e.g., query to see if a fan motor is currently running). If the air displacement device **509** is currently active, the process proceeds to box **619**. However, if the air displacement device **509** is inactive, then the process subsequently ends.

Moving to box **619**, the control circuitry on the conveyor segment **506** then deactivates the air displacement device **509**. For example, the control circuitry could send a signal or message to the airflow controller **559** that instructs the airflow controller **559** to turn off the motor controlling the air displacement device **509** (e.g., a fan motor). As another example, the control circuitry could send a signal or message to the airflow controller **559** that instructs the airflow controller **559** to adjust or decrease the amount of air being displaced by the air displacement device (e.g., increase speed of fan motor from a higher speed to a lower speed). Execution of the process then subsequently ends.

Although the functional elements detailed above are described as being implemented by the conveyor segment **506**, a similar method could be performed by the control application **516** (FIG. **5**). In such an alternative embodiment, the control application **516** could receive a reading from the pressure sensor in a manner similar to that described at box **603**. The control application **516** could then determine that the reading is above the threshold in a manner similar to that described at box **606**. The control application **516** could then determine whether the air displacement device **509** is active or not by querying the airflow controller **559** in a manner similar to that described in boxes **609** and **616**. Finally, the control application **516** could send a command to the airflow controller **559** to activate or deactivate the air displacement device **509** in a manner similar to that described in boxes **613** and **619**.

Referring next to FIG. **7**, shown is a flowchart that provides one example of the operation of a portion of the control application **516** according to various embodiments. It is understood that the flowchart of FIG. **7** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the control application **516** as described herein. As an alternative, the flowchart of FIG. **7** may be viewed as depicting an example of elements of a method implemented in the computing environment **503** (FIG. **5**) according to one or more embodiments.

Beginning with box **703**, the control application **516** determines that an item **546** (FIG. **5**) is present on a conveyor segment **506** (FIG. **5**). For example, the conveyor segment **506** could communicate to a reading or readings from one or more conveyor segment sensors **553** (FIG. **5**). The control application **516** could then determine that an item **546** was present (e.g., due to a change in weight being recorded or a pressure indicating a present of the item **546**). Other approaches may be used in various other embodiments.

Moving on to box **706**, the control application **516** identifies the item **546** on the conveyor segment **506**. For example, the control application **516** could send a command to the conveyor segment **506** to use a conveyor segment sensor **553** (e.g., an RFID reader) to obtain an item identifier **549** (FIG. **5**—e.g., read an RFID tag affixed to the item **546**) and return the result to the control application **516**. The control application **516** could then use item identifier as a search value of an item catalog **526** (FIG. **5**) to identify the item **546**.

Proceeding next to box **709**, the control application **516** sends a command to an airflow controller **559** to adjust the air flow rate of a respective air displacement device **509** (e.g., an air displacement device **509** mounted to the conveyor segment **506** or moving in tandem with the conveyor segment **506**). For example, the control application **516** could send an instruction to increase the air flow in order to increase the static friction between the item **546** and the surface of the conveyor segment **506** if the item **546** is a lightweight item **546** that is likely to become airborne at speed. As another example, the control application **516** could send an instruction to decrease the air flow (or even generate reverse air flow) in order to decrease the static friction between the item **546** and the surface of the conveyor segment **506** if the item **546** is a heavier item **546** and too much static friction would prevent the item from being sorted at a later point by the materials handling system.

Referring next to FIG. **8**, shown is a flowchart that provides one example of the operation of a portion of the control application **516** according to various embodiments. It is understood that the flowchart of FIG. **8** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the control application **516** as described herein. As an alternative, the flowchart of FIG. **8** may be viewed as depicting an example of elements of a method implemented in the computing environment **503** (FIG. **5**) according to one or more embodiments.

Beginning with box **803**, the control application **516** determines the current location **533** (FIG. **5**) of a conveyor segment **506** (FIG. **5**). This can be accomplished using any one or more of several approached. For instance, the conveyor segment **506** could determine its own current location **533** and report its current location **533** to the control application **516**. In other instances, the conveyor segment **506** could trigger some sensor to indicate its current location **533** along a track. As another example, the conveyor segment **506** could periodically broadcast a radio beacon that could be received by one or more sensors. The control application **516** could then use various multilateration approaches to determine the current location **533** of the conveyor segment **506** (e.g. time-delay on arrival, differences in signal strength, etc.). In other instances, as the conveyor segment **506** passed an image capture device (e.g., a camera) or some other sensor, the control application **516** could determine the current location **533** of the conveyor segment **506** based on its proximity to the sensor.

Proceeding to box **806**, the control application **516** sends a command to an airflow controller **559** to adjust the air flow rate of a respective air displacement device **509** (e.g., an air displacement device **509** mounted to the conveyor segment **506** or moving in tandem with the conveyor segment **506**). For example, the control application **516** could send an instruction to increase the air flow if the conveyor segment **506** is approaching a section of the track where increased static friction would be desirable (e.g., sharp turn, change in elevation, etc.). As another example, the control application **516** could send an instruction to decrease the air flow if the conveyor segment is approaching a section of the track where decreased static friction would be desirable. After sending the command, the process subsequently ends.

Referring next to FIG. **9**, shown is a flowchart that provides one example of the operation of a portion of the control application **516** according to various embodiments. It is understood that the flowchart of FIG. **9** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the control application **516** as described herein. As an alternative, the flowchart of FIG. **9** may be viewed as depicting an example of elements of a method implemented in the computing environment **503** (FIG. **5**) according to one or more embodiments.

Beginning with box **903**, the control application **516** determines the current air flow rate of an air displacement device **509** (FIG. **5**). This can be accomplished in several ways. For instance, the control application **516** could send a query to the airflow controller **559** (FIG. **5**) of the air displacement device **509** and receive a response indicating the current operating speed of the motor controlling the air displacement device **509**. The control application **516** could then calculate the air flow rate based on the current operating speed of the motor. As another example, the control application **516** could query an air displacement sensor **563** (FIG. **5**) and receive in response a reading indicating a measured amount of air flow.

Proceeding to box **906**, the control application **516** can determine if the current speed **543** (FIG. **5**) of the conveyor segment **506** (FIG. **5**) corresponding to the air displacement device **509** is optimal for the determined air flow rate. This determination can be based on a number of factors, such as the weight of an item **546** or a type of item **546** on the conveyor segment **506** or other conveyor segments **506** of the track. If the current speed **543** is determined to be optimal (e.g., the fastest safe operating speed when the air displacement device **509** is operating at the measured air flow rate), then the process ends. Otherwise, the process proceeds to box **909**.

Moving on to box **909**, the control application **516** can then send a command to the track that is moving the conveyor segment **506** (FIG. **5**). If the speed is too slow (e.g., the track can operate equally safely at a higher speed due to the airflow determined at box **903**), then the control application **516** can send a command to the track to increase the current speed **543** of the conveyor segments **506**. Similarly, if the speed is too fast (e.g., the track cannot operate safely at the current speed **543** because the airflow determined at box **903** is too low), then the control application can send a command to the track to decrease the current speed **543** of the conveyor segments **506** to the optimal track speed. Execution of the process subsequently ends.

Referring next to FIG. **10**, shown is a flowchart that provides one example of the operation of a portion of the control application **1003** according to various embodiments. It is understood that the flowchart of FIG. **10** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the control application **1003** as described herein. As an alternative, the flowchart of FIG. **10** may be viewed as depicting an example of elements of a method implemented in the computing environment **503** (FIG. **5**) according to one or more embodiments.

Beginning with box **1003**, the control application **516** determines the current speed **543** (FIG. **5**) of a conveyor segment **506** (FIG. **5**). For instance, the conveyor segment **506** could determine its own current speed **543** and report its current speed **543** to the control application **516** on a periodic basis. The current speed **543** could be measured using a conveyor segment sensor **553**, such as a speedometer. In another instance, the control application **516** could determine the location of the conveyor segment **506** at two different points in time and calculate the speed of the conveyor segment **506** based on the distance travelled between the two different points during the intervening interval of time.

Proceeding to box **1006**, the control application **516** sends a command to an airflow controller **559** to adjust the air flow rate of a respective air displacement device **509** (e.g., an air displacement device **509** mounted to the conveyor segment **506** or moving in tandem with the conveyor segment **506**). For example, the control application **516** could send an instruction to increase the air flow if the conveyor segment **506** is moving at a high rate of speed in order to prevent items from becoming airborne or otherwise "flying off" of the conveyor segment **506**. As another example, the control application **516** could send an instruction to decrease the air flow if the conveyor segment **506** is operating a lower rate of speed in order to save power, decrease static friction to avoid unintended jams of equipment, etc. After the command is sent, the process subsequently ends.

With reference to FIG. **11**, shown is a schematic block diagram of the computing environment **503** according to an embodiment of the present disclosure. The computing environment **503** includes one or more computing devices **1100**. Each computing device **1100** includes at least one processor circuit, for example, having a processor **1103** and a memory **1106**, both of which are coupled to a local interface **1109**. To this end, each computing device **1100** may include, for example, at least one server computer or like device. The local interface **1109** may include, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **1106** are both data and several components that are executable by the processor **1103**. In particular, stored in the memory **1106** and executable by the processor **1103** is the control application **516** and potentially other applications. Also stored in the memory **1106** may be a data store **519** and other data. In addition, an operating system may be stored in the memory **1106** and executable by the processor **1103**.

It is understood that there may be other applications that are stored in the memory **1106** and are executable by the processor **1103** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other programming languages.

A number of software components are stored in the memory **1106** and are executable by the processor **1103**. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor **1103**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **1106** and run by the processor **1103**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **1106** and executed by the processor **1103**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **1106** to be executed by the processor **1103**, etc. An executable program may be stored in any portion or component of the memory **1106** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, Universal Serial Bus (USB) flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **1106** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory **1106** may include, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may include, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may include, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **1103** may represent multiple processors **1103** or multiple processor cores and the memory **1106** may represent multiple memories **1106** that operate in parallel processing circuits, respectively. In such a case, the local interface **1109** may be an appropriate network that facilitates communication between any two of the multiple processors **1103**, between any processor **1103** and any of the memories **1106**, or between any two of the memories **1106**. The local interface **1109** may include additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **1103** may be of electrical or of some other available construction.

Although the control application **516** and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowcharts of FIGS. **6-10** show the functionality and operation of an implementation of portions of the control application **516** or control circuits of the conveyor segment **506**. If embodied in software, each block may represent a module, segment, or portion of code that includes program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that includes human-readable statements written in a programming language or machine code that includes numerical instructions recognizable by a suitable execution system such as a processor **1103** in a computer system or other system. The machine code may be converted from the source code through various processes. For example, the machine code may be generated from the source code with a compiler prior to execution of the corresponding application. As another example, the machine code may be generated from the source code concurrently with execution with an interpreter. Other approaches can also be used. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function or functions.

Although the flowcharts of FIGS. **6-10** show a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIGS. **6-10** may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIGS. **6-10** may be skipped or omitted. In addition, any number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

Also, any logic or application described herein, including the control application **516** or control circuits of the conveyor segment **506**, that includes software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **1103** in a computer system or other system. In this sense, the logic may include, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can include any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

Further, any logic or application described herein, including the control application **516** or control circuits of the conveyor segment **506**, may be implemented and structured in a variety of ways. For example, one or more applications described may be implemented as modules or components of a single application. Further, one or more applications described herein may be executed in shared or separate computing devices or a combination thereof. For example, a plurality of the applications described herein may execute in the same computing device **1100**, or in multiple computing devices in the same computing environment **503**.

Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiments without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Therefore, the following is claimed:

1. A system, comprising:
- a track;
- a tilt tray affixed to the track, the tilt tray comprising:
  - a perforated surface;
  - a pressure sensor connected to the perforated surface; and
  - a fan mounted underneath the perforated surface, the fan comprising a plurality of fan blades connected to a fan motor controlled by a fan controller;
- an electric rail mounted to the track that provides power to the tilt tray and the fan;
- a computing device in data communication with the fan and the tilt tray, the computing device comprising a processor and a memory; and
- machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to:
  - determine that an item is present on the tilt tray based at least in part on a reading generated by the pressure sensor;
  - determine an appropriate air pressure to generate in order to retain the item on the tilt tray when the tilt tray moves along the track at a particular speed, wherein the appropriate air pressure is determined based at least in part on the reading generated by the pressure sensor; and
  - send a command to the fan controller to adjust a speed of the fan motor to generate the appropriate air pressure.

2. The system of claim **1**, wherein the machine readable instructions further cause the computing device to:
- determine a current location of the tilt tray;
- determine an updated appropriate air pressure to generate to retain the item on the tilt tray when the tilt tray moves along the track at the particular speed at or proximate to the current location; and
- send a command to the fan controller to adjust the speed of the fan motor to generate the updated appropriate air pressure.

3. The system of claim **1**, wherein the machine readable instructions further cause the computing device to:

determine an updated speed of the tilt tray;

determine an updated appropriate air pressure to generate to retain the item on the tilt tray when the tilt tray moves along the track at the updated speed; and

send a command to the fan controller to adjust the speed of the fan motor to generate the updated appropriate air pressure.

4. A system, comprising:

a track;

a conveyor segment affixed to the track, the conveyor segment comprising an air permeable surface;

an air displacement device underneath the air permeable surface configured to move air through the air permeable surface, thereby increasing a static frictional force upon the air permeable surface;

a computing device in data communication with the air displacement device, the computing device comprising a processor and a memory; and

machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to:

determine that an item is present on the conveyor segment;

identify the item present on the conveyor segment; and

send a command to the air displacement device to adjust a flow rate based at least in part on an identification of the item.

5. The system of claim **4**, wherein the air displacement device comprises a fan.

6. The system of claim **4**, wherein the air displacement device comprises a reverse Venturi valve.

7. The system of claim **4**, wherein the air displacement device comprises a suction pump.

8. The system of claim **4**, wherein the conveyor segment comprises a tilt-tray.

9. The system of claim **4**, wherein the conveyor segment comprises a cross-belt segment and the air permeable surface comprises a perforated conveyor belt positioned at an angle relative to a direction of the track.

10. The system of claim **4**, further comprising an electric rail affixed to the track, wherein the electric rail provides power to the conveyor segment and the air displacement device.

11. The system of claim **4**, wherein:

the conveyor segment further comprises a pressure sensor connected to the air displacement device; and

the air displacement device is activated in response to receipt of a reading from the pressure sensor.

12. The system of claim **4**,

wherein the machine readable instructions stored in the memory, when executed by the processor, further cause the computing device to:

determine a current location of the conveyor segment on the track; and

send a command to the air displacement device to adjust a flow rate based at least in part on the current location of the conveyor segment on the track.

13. The system of claim **4**,

wherein the computing device is in data communication with the track and the machine readable instructions stored in the memory, when executed by the processor, further cause the computing device to:

determine a flow rate of the air displacement device; and

cause a change in speed of the conveyor segment based at least in part on the flow rate of the air displacement device.

14. The system of claim **4**,

wherein the computing device is in data communication with the conveyor segment and the machine readable instructions stored in the memory that, when executed by the processor, further cause the computing device to:

determine a current speed of the conveyor segment; and

send a command to the air displacement device to adjust a flow rate based at least in part on the current speed of the conveyor segment.

15. A system, comprising:

a track;

a conveyor segment affixed to the track, the conveyor segment comprising an air permeable surface;

a series of air displacement devices positioned above the track such that air exiting each air displacement device in the series of air displacement devices flows through the air permeable surface of the conveyor segment;

a computing device in data communication with individual air displacement devices in the series of air displacement devices, the computing device comprising a processor and a memory; and

machine readable instructions stored in the memory that, when executed by the processor, cause the computing device to:

determine a current location of a conveyor segment on the track; and

send a command to individual air displacement devices in the series of air displacement devices to adjust a flow rate based at least in part on the current location of the conveyor segment on the track.

16. The system of claim **15**, wherein the conveyor segment comprises a cross-belt segment and the air permeable surface comprises a perforated conveyor belt positioned at an angle relative to the direction of the track.

17. The system of claim **15**, wherein the conveyor segment comprises a conveyor belt.

18. The system of claim **15**, wherein the conveyor segment comprises a tilt tray.

19. The system of claim **15**, wherein at least one air displacement device in the series of air displacement devices is a reverse Venturi valve.

20. The system of claim **15**, wherein at least one air displacement device in the series of air displacement devices is a suction pump.

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